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RESEARCH ARTICLE

A review of *Trichogramma* Westwood parasitoids on eggs of *Thaumetopoea pityocampa* (Denis & Schiffermüller) in habitats of the Balkan Peninsula and Asia Minor

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Abstract

Studies on egg parasitoids of the pine processionary moth (*Thaumetopoea pityocampa*) were conducted during the period 1991-2018 in native localities of the pest on the Balkan Peninsula and in Asia Minor. In Bulgaria the biological material (2510 egg batches and 579273 eggs) was collected in 48 host localities. A number of 650 egg batches and 135611 eggs were studied from the Balkan countries (North Macedonia, Bosnia and Herzegovina, Albania and Greece), and in the Asian part of Turkey (Asia Minor), the biological material was examined from nine habitats. Eight species of egg parasitoids (*Ooencyrtus pityocampae*, *Baryscapus servadeii*, *B. transversalis*, *Pediobius bruchicida*, *Anastatus bifasciatus*, *Eupelmus vesicularis*, *E. vladimiri* and *Trichogramma* sp.) were found. The total regulating effect of egg parasitoids in Bulgaria was on average 17.6%, and in the other Balkan countries – 24.9%. *Trichogramma* sp. was found in 63.1% of the analysed samples in Bulgaria and in 55.6% from the neighboring countries. The percent of parasitism of *T. pityocampa* eggs by *Trichogramma* sp. was low - on average 0.39% for Bulgaria and 0.73% for the other Balkan countries. The relative share of the species in the total percentage of parasitised eggs for Bulgaria and the other countries was 2.2% and 2.9%, respectively.

Keywords

Trichogramma sp., *Thaumetopoea pityocampa*, Bulgaria, Balkan Peninsula, Asia Minor

Introduction

The pine processionary moth (*Thaumetopoea pityocampa*) (Denis & Schiffermüller, 1775) (Lepidoptera: Notodontidae) is an economically important pest native to the Mediterranean region. The pest is considered a major defoliator in coniferous forests, and is known to cause severe and frequent damage mainly on pine and cedar trees (Kailidis, 1962; Demolin, 1969; Moura et al., 1999; Schmidt et al., 1990; Battisti et al., 2015). There are different effects of damage caused by *T. pityocampa*. The most serious attacks occure in physiologically weakened pine forests planted on eroded terrains, causing substantial tree mortality. The severe outbreaks and defoliation incidence reduce the productivity of attacked trees, causing economic losses in the forests. The caterpillars of the pest have thousands of tiny hairs which contain an urticating, or irritating, protein called thaumetopoein (Lamy, 1990). If these hairs come into contact with people and animals, they can cause allergic reactions, which has an extremely negative effect on the recreational functions of coniferous forests around resort villages.

Several natural enemies of the pine processionary moth including predators, pathogens, parasites and parasitoids can reduce the harmful effect of the pest in its range. Studies of egg parasitoids (Biliotti, 1958; Masutti, 1964; Geri, 1984; Battistti, 1985-1986; Schmidt, Douma-Petridou, 1989; Belin et al., 1990; Schmidt, 1990; Halperin, 1990; Tiberi, 1990; Tsankov, 1990; Kitt, Schmidt, 1993; Tsankov, Mirchev, 2003) showed high levels of parasitism in some areas. In these ares, the complex of parasitoides were the most significant natural regulators of the host's population density. Eight species of egg parasitoids have been found on the host, among which *Oencyrtus pityocampae* (Mercet, 1921) and *Baryscapus servadeii* (Domenichini, 1965) have been regarded as the most numerous and effective (Georgiev et al., 2021; Mirchev et al., 2021). The most effective parasitoids were mainly studied, and less interest was shown to the remaining ones. However, information on *Trichogramma* sp. as an egg parasitoid of the pine processionary moth can be found in the studies of several authors (Thompson, 1954; Ceballos, Sanches, 1962; Garcia-Fuéntes, 1965; Herting, 1976; Tiberi, 1978; Harapin, 1986; Tiberi, Roversi, 1987; Viggiani, Laudonia, 1989; Bellin et al., 1990; Tsankov, 1990; Masutti et al., 1993; Jamaâ et al., 1996; Schmidt et al. 1999; Sebti et al., 2022, etc.).

The aim of the present study was to establish the participation of *Trichogramma* Westwood in the complex of egg parasitoids of pine processionary moth in the countries of the Balkan Peninsula and Asia Minor, and to clarify its regulating effect on the pest's population densty.

Material and methods

The study was conducted in the period 1991-2018 by collecting egg butches of *Thaumetopoea pityocampa*. In Bulgaria, 103 samples containing 2510 egg batches and 579273 eggs were collected from 48 localities divided into three geographical regions: Central Bulgaria, the Eastern Rhodopes and Southwestern Bulgaria. A total of 650 egg

batches and 135611 eggs were studied from the Balkan countries: Greece (thirteen sites), Albania (two sites), North Macedonia (one site) and Bosnia and Herzegovina (one site). In the Asian part of Turkey (Asia Minor) 215 egg batches and 42676 eggs were taken from nine localities of the pest.

The complex of parasitoids was identificatied in laboratory conditions at Forest Research Institute in Sofia. The covering scales of the butches were removed following the methodology of Tsankov et al. (1996). They were placed individually in cotton-plugged tubes and stored at room temperature. After the end of the parasitoids' flight, final analyses of the samples were made by openning the eggs without exit holes. The effect of *Trichogramma* sp. was calculated based on the number of parasitised host's eggs. Data were statistically processed using MS Excel (2016).

Results

In the Bulgarian studied sites, a diversity in the phenological form of *Thaumetopoea pityocampa* was distinguished in the divided three geographical areas (Table 1): the habitats in the Southwestern Bulgaria were occupied by the typical Mediterranean (winter) form (caterpillars overwinter in the nests and pupate in the spring). In the Eastern Rhodopes (the lands of villages Kirkovo, Yanino, Dyulitsa, Medevtsi, Kayaloba, Drangovo, Jerovo, Domishte, and the town of Kardjali), summer phenological form mainly occurs (development of the caterpillars ends in the autumn, and they hibernate in the pre-pupa stage in the soil). In Central Bulgaria, both phenological forms inhabit the same biotopes. In the rest of the Balkan countries, the winter phenological form occures.

In this study seven species of primary and one secondary parasitoids (order Hymenoptera) were found on the eggs of *T. pityocampa*: *Ooencyrtus pityocampae* (Mercet, 1921), *Baryscapus servadeii* (Domenichini, 1965), *Baryscapus transversalis* Graham, 1991, *Pediobius bruchicida* (Rondani, 1872), *Anastatus bifasciatus* (Geoffroy, 1785), *Eupelmus* (*Macroneura*) *vesicularis* (Retzius, 1783), *Eupelmus* (*Macroneura*) *vladimiri* Fusu, 2017 and *Trichogramma* sp. There was no sample in the study that represented the full species diversity of the parasitoids. In the Bulgarian samples, seven species of the parasitoids were found in the collections from 2018 in Kirkovo and Satovcha (Table 1).

The results showed that the egg parasitoids were a serious regulator of the number of the pine processionary moth population density in the studied sites. In Bulgaria, the mean observed parasitism of the eggs was 17.6%. The rate of parasitism in the samples from the Eastern Rhodopes varied between 0.3% (Hvoyna, 1995) and 38.4% (Komuniga, 2016) (Table 1), and the mean parasitism reached 17.5%. In Southwestern Bulgaria the average percentage of emerged parasitoids was 18.1%, with variations in the samples - from not parasitised (Kyustendil, 1999) to 43.8% (Ploski, 1994). The mean observed parasitism was slightly lower in the sites from Central Bulgaria (16.7%), but high rates of emerged parasitoids were recorded in Rozino (2016) - 49.3% and in Klisura (2017) - 43.2%.

Table 1. Participation of *Trichogramma* sp. in the parasitoid complex on the eggs of *Thaumetopoea pityocampa* in habitats in Bulgaria

Site	Year	Eggbatches, n	Eggs, n	Parasitised eggs		Parasitised eggs of *T.* sp., %	Share of *T.*sp in parasitised eggs, %	Parasitoids*
				n	%			
Habitats in the Southwestern Bulgaria								
Dupnitsa	1994	34	8473	716	8.5	-	-	O.p.;B.s.;B.t.
	1995	22	5259	858	16.3	0.17	1.0	O.p.;B.s.;B.t.;A.b.; T.sp.
Kyustendil	1994	24	5874	24	0.4	0.4	100	T.sp.
	1995	37	8113	255	3.1	3.0	94.1	O.p.;B.s.;B.t.; T.sp.
	1997	16	3427	49	1.4	1.0	69.4	B.s.;T.sp.
	1998	5	904	60	6.6	-	-	O.p.;B.s.;B.t.
	1999	5	1021	0	0.0	-	-	-
	2014	9	2018	393	19.5	0.05	0.25	O.p.;A.b.; T.sp.
Nevestino	2016	22	5360	455	8.5	0.07	0.9	O.p.;B.s.;B.t.;A.b.;T.sp.
Vetren	2013	33	8166	1877	23.0	0.26	1.1	O.p.;B.s.;B.t.;A.b.; T.sp.
	2014	30	7424	1333	18.0	0.08	0.45	O.p.;B.s.;B.t.;A.b.; T.sp.
	2016	22	5360	924	17.3	0.07	0.43	O.p.;B.s.;B.t.;A.b.; T.sp.
Rila Monastery	2016	6	1478	205	13.9	0.5	3.4	O.p.;B.s.;B.t.;A.b.;T.sp.
Ploski	1991	30	6586	1395	21.2	0.09	0.4	O.p.;B.s.;B.t.;A.b.; T.sp.
	1992	26	6263	836	13.3	0.30	2.3	O.p.;B.s.;B.t.;A.b.; T.sp.
	1994	17	3362	1471	43.8	0.06	0.1	O.p.;B.s.;B.t..; T.sp.
	1995	21	5314	756	14.2	0.21	1.5	O.p.;B.s.;B.t.;A.b.; T.sp.
Sandansky	1997	12	2317	392	16.9	-	-	O.p.;B.s.;B.t.
	2017	23	5161	280	5.4	-	-	O.p.;B.s.;B.t.;A.b.; E. vl.
	2016	20	4839	861	17.8	0.3	1.6	O.p.;B.s.;B.t.;A.b.;T.sp.
Parvomay	2017	40	8638	1075	12.4	0.4	3.3	O.p.;B.s.;B.t.;A.b.;T.sp.
	2018	59	15097	3495	23.2	0.2	0.7	O.p.;B.s.;B.t.;A.b.;T.sp.
Marikostinovo	1991	89	21592	6418	29.7	0.017	0.07	O.p.;B.s.;B.t.;A.b. T.sp.
	1992	58	14065	3225	22.9	-	-	O.p.
	1993	11	2358	457	19.4	-	-	O.p.;B.s.;B.t.;A.b.;E.v.
	1994	37	8252	2673	32.4	-	-	O.p.;B.s.;B.t.;A.b.
	1995	58	14282	3194	22.4	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
	1996	32	7373	1977	26.8	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
Slashten	1994	17	3554	838	23.6	0.03	0.11	O.p.;B.s.;B.t.;T.sp.
	2000	18	3726	973	26.1	-	-	O.p.;B.s.;B.t.
	2002	28	6132	1245	20.3	0.2	1.0	O.p.;B.s.;B.t.;A.b.;T.sp.
	2008	11	2478	320	12.9	-	-	O.p.;B.s.;B.t.;A.b.
Satovcha	1994	17	3554	1025	28.8	0.03	0.1	O.p.;B.s.;B.t.;A.b.; P.b.;T.sp.
	2002	28	6132	1245	20.3	0.21	1.04	O.p.;B.s.;B.t.;A.b.;T.sp.
	2016	28	6532	1660	25.4	-	-	O.p.;B.s.;B.t.;A.b.
	2017	25	5664	624	11.0	0.04	0.3	O.p.;B.s.;B.t.;A.b.;T.sp.
	2018	54	12618	1346	10.7	0.4	3.8	O.p.;B.s.;B.t.;A.b.;P.b.; E.vl.; T.sp.

Gotse Delchev	2016	30	7197	601	8.4	0.4	5.0	O.p.;B.s.;B.t.;A.b.;T.sp.
	2017	21	4738	501	10.6	0.02	0.2	O.p.;B.s.;B.t.;A.b.;T.sp.
	2018	8	1620	127	7.8	-	-	O.p.;B.s.;B.t.;A.b.
Garmen	2016	10	2206	281	12.7	0.05	0.4	O.p.;B.s.;B.t.;A.b.
	2017	32	6633	865	13.0	0.2	1.2	O.p.;B.s.;B.t.;A.b.; E. vl.;T.sp.
	2018	5	1033	114	11.0	0.1	0.9	O.p.;B.s.;B.t.; T.sp.
Σ		1130	262193	47419	18.1			
Habitats in the Eastern Rhodopes								
Ivaylovgrad	2009	22	5651	1077	19.1	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
	2010	31	7754	1982	25.6	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
	2012	32	8944	1982	22.2	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
	2016	39	10867	2487	22.9	-	-	O.p.;B.s.;B.t.;A.b.
	2018	20	5751	809	14.1	-	-	O.p.;B.s.;B.t.;A.b.
Kardzhali	1994	30	5997	1456	24.3	0.33	1.37	O.p.;B.s.;B.t.;A.b.; T.sp.
	1995	22	4606	1263	27.4	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
	1996	15	2957	762	25.8	-	-	O.p.;B.s.;B.t.;A.b.
	2014	53	10335	3534	34.2	-	-	O.p.;B.s.;B.t.;A.b.
Yanono	2016	26	5428	1109	20.4	0.04	0.18	O.p.;B.s.;B.t.;A.b.;T.sp.
Dyulitsa	2016	7	1815	184	10.1	-	-	O.p.;B.s.;B.t.;A.b.
Medevtsi	2016	30	6825	602	8.8	-	-	O.p.;B.s.;B.t.;A.b.
Kayaloba	2016	18	3337	802	24.0	0.03	0.1	O.p.;B.s.;B.t.;A.b.;T.sp.
Drangovo	2016	6	1348	466	34.6	-	-	O.p.;B.s.;B.t.;A.b.
Dzherovo	2016	20	4510	321	7.1	-	-	O.p.;B.s.;B.t.;A.b.
Domishte	2016	30	7164	1307	18.2	-	-	O.p.;B.s.;B.t.;A.b.
Kirkovo	2017	199	42952	7642	17.8	0.02	0.1	O.p.;B.s.;B.t.;A.b.;E. vl.;T.sp.
	2018	30	6367	382	6.0	0.09	1.6	O.p.;B.s.;B.t.;A.b.;E. vl.;P.b.;T.sp.
Kandilka	2018	17	3780	532	14.1	0.3	1.9	O.p.;B.s.;B.t.;A.b.;T.sp.
Momchilgrad	2018	17	3639	162	4.5	-	-	O.p.;B.s.;B.t.;A.b.
Zlatograd	2018	50	10225	663	6.5	1.3	20.8	O.p.;B.s.;B.t.;A.b.;T.sp.
	2016	25	6465	435	6.7	2.3	34.5	O.p.;B.s.;B.t.;A.b.;T.sp.
Asenovgrad	2017	16	2990	179	6.0	2.6	44.1	O.p.;B.s.;B.t.;A.b.;E.vl;T.sp.
	2018	8	1740	163	9.4	9.0	95.7	O.p.;B.s.;B.t.;A.b.;T.sp.
Komuniga	2016	8	1851	710	38.4	1.2	3.1	O.p.;B.s.;B.t.;A.b.;T.sp.
	2017	26	6571	1376	20.9	0.05	0.2	O.p.;B.s.;B.t.;A.b.;T.sp.
Rakitovo	2016	5	1154	43	3.7	0.3	7.0	O.p.;B.s.;B.t.;A.b.;T.sp.
Radilovo	2016	10	2724	182	6.7	-	-	O.p.;B.s.;B.t.;A.b.
Hvoyna	1995	14	2350	7	0.3	-	-	A.b.
Σ		826	186097	32619	17.5			
Habitats in Central Bulgaria								
Rosino	1996	8	1675	449	26.8	0.36	1.34	O.p.;B.s.;B.t; T.sp.
	2016	17	3441	1698	49.3	0.03	0.06	O.p.;B.s.;B.t.;A.b.;T.sp.
Klisura	1994	9	2105	147	7.0	0.9	12.9	O.p.;B.s.; T.sp.
	2016	29	6766	1472	21.8	0.03	0.1	O.p.;B.s.;B.t.;A.b.;T.sp.
	2017	12	2655	1147	43.2	0.1	0.3	O.p.;B.s.;B.t.;A.b.;T.sp.
	2018	22	5053	521	10.3	7.4	72.2	O.p.;B.s.;B.t.;A.b.;T.sp.

Site	Year	Eggbatches, n	Eggs, n	Parasitised eggs n	Parasitised eggs %	Parasitised eggs of *T.* sp., %	Share of *T.*sp in parasitised eggs, %	Parasitoids*
G. Dryanovo	2016	10	2569	874	34.0	0.7	2.1	O.p.;B.s.;B.t.;A.b.;T.sp.
	2017	7	1557	576	37.0	0.06	0.2	O.p.;B.s.;B.t.;A.b.;T.sp.
	2018	41	9194	2053	22.3	1.3	6.0	O.p.;B.s.;B.t.;A.b.;T.sp.
Karlovo	2016	8	2183	66	3.0	0.09	3.0	O.p.;B.s.;B.t.;A.b.;T.sp.
Hisarya	2016	35	8677	684	7.9	0.08	1.0	O.p.;B.s.;B.t.;A.b.;T.sp.
	2018	24	6332	271	4.3	0.7	15.5	O.p.;B.s.;B.t.;A.b.;T.sp.
Banya	1992	31	7647	1210	15.8	2.1	13.1	O.p.;B.s..;A.b.;T.sp.
	1993	11	2610	640	24.5	0.5	2.2	O.p.;B.s.;T.sp.
	1996	11	2318	324	14.0	0.17	1.2	O.p.;B.s.;A.b.; T.sp.
	1999	40	7990	1980	24.8	0.19	0.76	O.p.;B.s.;B.t.;A.b.; P.b.;T.sp.
Kurtovo	1991	28	6355	1580	24.9	0.52	2.1	O.p.;B.s.;B.t.;A.b.; E.v..;T.sp.
	1995	4	811	183	22.6	-	-	O.p.;B.s.
	1996	9	1813	78	4.3	-	-	O.p.;B.s.
Kazanlak	2016	20	4965	367	7.4	1.4	19.6	O.p.;B.s.;B.t.;A.b.;T.sp.
Tyulbeto	2016	31	7500	902	12.0	0.6	4.9	O.p.;B.s.;B.t.;A.b.;T.sp.
Koprinka Dam	2016	21	5545	767	13.8	0.5	3.3	O.p.;B.s.;B.t.;A.b.;T.sp.
Maglizh	2016	12	3262	280	8.6	0.1	1.4	O.p.;B.s.;B.t.;A.b.;T.sp.
	2017	13	3267	612	18.7	0.6	3.3	O.p.;B.s.;B.t.;A.b.;T.sp.
K.Marinovo	2016	7	1858	41	2.2	-	-	O.p.;B.s.;B.t.;A.b.
	2017	13	2894	255	8.8	-	-	O.p.;B.s.;B.t.;A.b.
Sl. Kladenets	2016	36	8279	359	4.3	-	-	O.p.;B.s.;B.t.;A.b.
Chehlare	2016	13	3473	170	4.9	-	-	O.p.;B.s.;B.t.;A.b.
Pazardzhik	2016	11	2686	352	13.1	-	-	O.p.;B.s.;B.t.;A.b.
Elshitsa	2016	5	1418	110	7.8	-	-	O.p.;B.s.;B.t.;A.b.
Σ		554	130983	21936	16.7			

* O.p. - *Ooencyrtus pityocampae*; B.s. - *Baryscapus servadeii*; B.t. - *Baryscapus transversalis*; A.b. - *Anastatus bifasciatus*; E. v. - *Eupelmus* (*Macroneura*) *vesicularis*; E. vl. - *Eupelmus* (*Macroneura*) *vladimiri*; P.b. - *Pediobius bruchicida*; T.sp. - *Trichogramma* sp.

In the other studied countries, the largest number of parasitoids (six species) were found in Igdecik in Turkey (*O. pityocampae*, *B. servadeii*, *B. transversalis*, *A. bifasciatus*, *P. bruchicida* and *Trichogramma* sp.) (Table 2). The average rate of parasitisied eggs was significantly higher – 24.9%. Parasitism in individual samples ranged from 7.3% in Attabey, Turkey to 48.9% in Timonia, Greece (Table 2).

Table 2. Participation of *Trichogramma* sp. in the parasitoid complex on the eggs of *T. pityocampa* in habitats in Balkan Peninsula and Asia Minor

Site	Year	Eggbatches, n	Eggs, n	Parasitized eggs		Parasitised eggs from *T.* sp.,%	Share of *T.*sp in parasitised eggs, %	Parasitoids*
				n	%			
Balkan Peninsula								
North Macedonia								
Ohrid	1999	19	4125	419	10.2	1.0	10.3	O.p.;B.s.; P.b.;T.sp.
	2004	29	6837	1085	15.9	2.2	13.8	O.p.;B.s.; A.b.; P.b.;T.sp.
Albania								
Voskopojë	1997	18	3762	812	21.6	1.5	6.8	O.p.;B.s.;B.t; T.sp.
Qarr	1997	14	2580	351	13.6	-	-	O.p.;B.s.;B.t
Greece								
Vrachneika	1996	32	7179	2033	28.3	-	-	O.p.;B.s.;B.t.;A.b.
Fteri-Egio	1996	20	3968	529	13.3	-	-	O.p.;B.s.;B.t.
Patras	1997	31	7871	2206	28.0	-	-	O.p.;B.s.;B.t.;A.b.; P.b.
Kalogria	1996	30	7276	1066	14.7	-	-	O.p.;B.s.;B.t.;A.b.
Kalogria	1997	39	7018	2574	36.7	-	-	O.p.;B.s.;A.b.
Hydra	1996	11	1975	742	37.6	-	-	O.p.;B.s.;B.t.
Athens	1999	24	4789	823	17.2	-	-	O.p.;B.s.;B.t.
Amfissa	1999	23	4507	1998	44.3	-	-	O.p.;B.s.;B.t.
Asprovalta	1999	11	2143	129	6.0	-	-	O.p.;B.s.
Skidia	2017	48	10280	3502	34.1	1.2	3.4	O.p.;B.s.;B.t.;A.b.;T.sp.
Thimonia	2017	24	5374	2626	48.9	3.6	7.4	O.p.;B.s.;B.t.;A.b.;T.sp.
Alyki	2017	22	4324	1843	42.6	4.0	9.3	O.p.;B.s.;B.t.;T.sp.
Panagia	2017	2	413	161	39.0	1.5	3.7	O.p.;B.s.;T.sp.
Bosnia and Herzegovina								
Borac	2013	38	8514	594	7.0	0.05	0.7	O.p.;B.s.;B.t.;A.b..;T.sp.
Asia Minor								
Turkey								
Iskenderun	2000	13	2382	794	33.3	0.08	0.3	O.p.;B.s.;P.b.;T.sp.
Derebogazi	1998	21	4544	1515	33.3	0.6	1.8	O.p.;B.s.;B.t.; P.b.;T.sp.
Iğdecik	1998	34	6812	1766	25.9	0.2	0.6	O.p.;B.s.;B.t.;A.b.;P.b.;T.sp.
Gönen	1998	57	11673	2757	23.6	1.0	4.0	O.p.;B.s.;B.t.;T.sp.
Isparta	2000	24	4494	558	12.4	1.1	9.1	O.p.;B.s.;T.sp.
Atabey	2000	12	2254	165	7.3	1.6	21.8	O.p.;B.s.;B.t.T.sp.
Gölhisar	1998	20	4427	1157	26.1	-	-	O.p.;B.s.;B.t.; P.b.
Bodrum	2000	18	3618	1351	37.3	-	-	O.p.;B.s.
Köycegiz	2000	16	2472	234	9.5	0.4	4.7	O.p.;B.s.;T.sp.
Σ		650	135611	33790	24.9			

* O.p. - *Ooencyrtus pityocampae*; B.s. - *Baryscapus servadeii*; B.t. - *Baryscapus transversalis*; A.b. - *Anastatus bifasciatus*; P.b. - *Pediobius bruchicida;* T. sp. - *Trichogramma* sp.

In Bulgaria, *Trichogramma* sp. was found in 62.1% of all analysed samples (Table 3). The average percent of parasitisied eggs varied with the different geographical regions: 44.8% in the sites from the Eastern Rhodopes, 67.4% in Southwestern Bulgaria and 74.2% in Central Bulgaria. In the other Balkan countries and Turkey, the species was registered in more than half of the samples – 55.6%. The highest value of emerged parasitoids was reported in Turkey (77.8%), and the lowest - in Greece (30.8%).

The regulatory effect of *Trichogramma* sp. on the number of the pine processionary moth was low - on average 0.39% for Bulgaria and almost twice higher (0.73%) for the other Balkan countries and Turkey. Its share in the total percentage of parasitised eggs was also low, 2.2% and 2.9% respectively for Bulgaria and the other countries (Table 3).

Table 3. Quantitative parameters of regulatory role of *Trichogramma* sp. in the egg stage of the population of the pine processionary moth

Parameters	**Samples**			
	Bulgaria		**Balkan Peninsula and Asia Minor**	
	n	**%**	**n**	**%**
Number of samples	103	100	27	100
Samples with *Trichogramma* sp.	64	62.1	15	55.6
Total number of eggs of *T. pityocampa*	579273	100	135611	100
Parasitised eggs of *T. pityocampa*	101974	17.6	33790	24.9
Parasitised eggs from *Trichogramma* sp.	2233	0.39	993	0.73
Share of *Trichogramma* sp. in parasitised eggs	2233	2.2	993	2.9

Several deviations in the percent of parasitisied eggs were recorded in the samples from Bulgaria. In Asenovgrad (2018), 9.4% of *T. pityocampa* eggs were parasitisied, of which 95.7% by *Trichogramma* sp. (Table 1). In Kyustendil (newly infested location of the pine processionary moth), only *Trichogramma* sp. was found several years after the incidence of the pest, but the regulating effect was extremely low – 0.4%.

In the Eastern Rhodopes, *Trichogramma* sp. was found in 13 of the total 29 samples, and in 61.5% of them the parasitised eggs of *T. pityocampa* were <1.0%, in 30.8% was <3.0% and only in one sample (Asenovgrad) was 9.0%. The results were similar in the other two geographical regions. In Southwestern Bulgaria, out of 29 samples with *Trichogramma* sp., the parasitisation by this parasitoid was below 1.0% in 96.6% of the samples, and 3.0% in only one sample. In Central Bulgaria, out of 23 samples with *Trichogramma* sp., in 19 of them the infestation was <1.0%, in three samples it was between 1.0% and 3.0%, and in one sample it was 7.4%.

In the samples collected in other countries, the average percent of eggs parasitisied by *Trichogramma* sp. was 0.73%, and the share of the species in the total numbers of parasitisatisied eggs was 2.9%. The highest value was recorded in two localities in

Greece: 4.0% (Aliki) and 3.6% (Timonia), which were with the highest values of total parasitisied eggs – 42.6% and 48.9, respectively (Table 2).

The reducing effect of *Trichogramma* sp. in the samples from North Macedonia was 1.0-2.2%, but its relative share was 10.3-13.8%. The parasitoid was found in seven studied samples from Turkey, where its regulatory effect was 0.05-1.6%. Amongest the samples from Greece, *Trichogramma* sp. was found only in four sites located on the Thassos Island – Skidia, Thimonia, Alyki and Panagian (Table 2).

Discussion

The results of this study outline the role of *Trichogramma* sp. as a regulating effect on *Thaumetopoea pityocampa* population density. It was confirmed that the representatives of the genus *Trichogramma* were common in the parasitoid complex found in the eggs of the pest. Three *Trichogramma* species were reported as a parasitoids of *T. pityocampa - Trichogramma embryophagum* (Hartig, 1838) (Herting, 1976; Tiberi, 1978; Tiberi, Roversi, 1987; Harapin, 1986; Viggiani, Laudonia, 1989; Tsankov, 1990; Masuti et al., 1993; Jamaâ et al., 1996), *Trichogramma evanescens* Westwood, 1833 (Thompson, 1954; Garcia-Fuéntes, 1965), and *Trichogramma semblidis* (Aurivillius, 1898) (Ceballos, Sanches, 1962; Herting, 1976).

In the Chréa National Park in Algeria *T. embryophagum* parasitised between 1.95 and 8.81% of the eggs of pine processionary moth during the period 2010-2014 (Sebti et al., 2022). Two more species of egg parasitoids (*O. pityocampae* and *B. servadeii*) were found in cedar plantations in Algeria, but *T. embryophagum* dominated (Ayache et al., 2021). In the Chelia area near Batna the parasitoid was second after *B. servadeii* (Messaadia et al. (2021). Single parasitised eggs of *Trichogramma* sp. were reported by Tsankov et al. (1995).

Trichogramma sp. was found in some areas in Spain. The total rate of parasitism of *T. pityocampa* eggs was between 11.3% and 31.7%, and the share of *Trichogramma* in the parasitoid complex ranged from 2.7% to 32.9% (Schmidt et al., 1999).

In the area of northern Italy, *Trichogramma* sp. was reported as the dominant species, constituting 71.5% of all emerged parasitoids from eggs of pine processionary moth (Zovi et al., 2006).

Avci (2003) reported that *Trichogramma brassicae* Bezdenko, 1968 was found in plantations of *Cedrus libani* on *Traumatocampa ispartaensis* Doğanlar & Avcı, 2001 in the Western Taurus Mountain Range near the city of Isparta in Turkey, with host eggs parasitized at 0.5-1.1%.

In northern Greece, *Trichogramma* sp. was reported in the region of Kassandra, where its abundance was relatively low to other parasitoids (0.1-0.2%), but was not found in Kalogria in the Peloponnese (Bellin et al., 1990).

In conclusion it could be noted that *Trichogramma* sp. is an essential element of the egg parasitoid complex of *Thaumetopoea pityocampa* in many habitats of its range. In some areas the species is dominant or at least numerous in the complex, especially

in territories newly occupied by the host. The results of the present study lead to the conclusion that in the Balkan Peninsula and Asia Minor, *Trichogramma* sp. is a common accompanying species in the general parasitoid complex, but the impact on the pest number is mostly insignificant.

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